Alabama	0.58
Mississippi	0.58
South Carolina	0.55
North Carolina	0.51

2.5. BURIED, AERIAL, AND UNDERGROUND PLACEMENT FRACTION

Definition: Outside plant structure refers to the set of facilities that support, house, guide, or otherwise protect distribution and feeder cable. There are three types of structure: aerial, buried, and underground.

a) Aerial Structure

Aerial structure includes poles and associated hardware.[11] Pole investment is a function of the material and labor costs of placing a pole. A user-adjustable input adjusts the labor component of poles investment to local conditions. The Hatfield Model computes the total investment in aerial distribution and feeder structure within a CBG by evaluating relevant parameters, including the distance between poles, the investment in the pole itself, the total cable sheath mileage, and the fraction of aerial structure along the route.

Poles are assumed to be 40 foot Class 4 poles. The spacing between poles for aerial cable is fixed within a given density range, but may vary between density ranges.

b) Buried Structure

Buried structure consists of trenches and related protection against water and other intrusions. The additional cost for protective sheathing and waterproof filling of buried cable is a fixed amount per foot in the case of fiber cable, and is a multiplier of cable cost in the case of copper cable.[12] The total investment in buried structure is a function of total route mileage, the fraction of buried structure, investment in protective sheathing and filling and the density-range-specific cost of trenching.

c) Underground Structure

Underground structure consists of conduit and, for feeder plant, manholes and pullboxes. Manholes are used in conjunction with copper cable routes; pullboxes are used with fiber cable. The total investment in a manhole varies by density zone, and is a function of the following investments: materials, frame and cover, excavation, backfill, and site delivery. Investment in fiber pullboxes is a function of materials and labor. Underground cables are housed in conduit facilities that extend between manholes or pullboxes. The total investment in underground structure is a function of total route mileage, the fraction of underground structure, investment in conduit manholes, and pullboxes, and the cost of trenching needed to hold the conduit.

In each line density range, there may be a mixture of aerial, buried, and underground structure. For example, in downtown urban areas it is frequently necessary to install cable in underground conduit

[11] In the two highest density zones, aerial structure is also assumed to consist of intrabuilding riser cable and "block cable" attached to buildings. In HM 3.1, this "aerial" structure does not include poles.

[12] The default values for sheathing are an additive $.20 per foot for fiber and a multiplier of 1.04 for copper. The different treatment reflects the fact that the outside dimension of fiber cable is essentially constant for different strand numbers, while the dimension of copper cable increases with the number of pairs it contains.

systems, while rural areas may consist almost exclusively of aerial or direct-buried plant.

Users can adjust the mix of aerial, underground and buried cable assumed within the Hatfield model. These settings may be made separately by density zone for fiber feeder, copper feeder, and copper distribution cables.

Default Values:

Distribution Cable Structure Fractions			
Density Zone	Aerial/Block Cable	Buried Cable	Underground Cable (calculated)
0-5	.25	.75	*0*
5-100	.25	.75	*0*
100-200	.25	.75	*0*
200-650	.30	.70	*0*
650-850	.30	.70	*0*
850-2,550	.30	.70	*0*
2,550-5,000	.30	.65	*.05*
5,000-10,000	.60	.35	*.05*
10,000+	.85	.05	*.10*

Support:

Aerial/Block Cable:

"The most common cable structure is still the pole line. Buried cable is now used wherever feasible, but pole lines remain an important structure in today's environment."[13]

Where an existing pole line is available, cable is normally placed on the existing poles. Abandoning an existing pole line in favor of buried plant is not usually done unless such buried plant provides a much less costly alternative.

HM 3.1 accounts for drop wire separately. Cable attached to the [out]sides of buildings, normally found in higher density areas, are also appropriately classified to the aerial cable account.
To facilitate modeling, HM 3.1 reasonably includes Intrabuilding Network Cable under its treatment of aerial cable.

Therefore, the default percentages above 2,550 lines per square mile indicate a growing amount of block and intrabuilding cable, rather than cable placed on pole lines (although existing joint use pole lines are also more prevalent in older, more dense neighborhoods built prior to 1980.

Buried Cable:

Default values in HM 3.1 reflect an increasing trend toward use of buried cable in new subdivisions. Since 1980, new subdivisions have usually been served with buried cable for several reasons. First, before 1980, cables filled with water blocking compounds had not been perfected. Thus, prior to that time, buried cable was relatively expensive and unreliable. Second, reliable splice closures of the type required for buried facilities were not the norm. And third, the public now clearly desires more out-of-sight plant for both esthetic and safety-related reasons. Contacts with telephone outside plant engineers, architects and property developers in several states confirm that in new subdivisions, builders typically not only prefer

[13] *BOC Notes on the LEC Networks - 1994*, Bellcore, p. 12-41.

buried plant that is capable of accommodating multiple uses, but they usually dig the trenches at their own expense and place power, telephone, and CATV cables in the trenches, if the utilities are willing to supply the materials. Thus, many buried structures are available to the LEC at no charge.

Underground Cable:

Underground cable, conduit, and manholes are primarily used for feeder and interoffice transport cables, not for distribution cable. Distribution plant in congested, extensively paved, high density areas usually runs only a short distance underground from the SAI to the block terminal, thus it requires no intermediate splicing chambers. In high density residential, distribution cables are frequently run from pole lines, under a street and back up onto a pole line, or from buried plant, under a street and back to a buried cable run. Such conduit runs are short enough to not require a splicing chamber or manhole and are therefore classified to the aerial or buried cable account, respectively.

There may be rare exceptions where distribution cable from a SAI is so long that it requires an underground splicing chamber (manhole). Sometimes feeder cable will be extended, via a lateral, into a SAI, and distribution pairs in the same feeder stub will run back into the same manhole for further routing to aerial or buried structures down a street. In those cases, manholes and conduit were placed for feeder cable and have already been accounted for in the cost of feeder plant structure. Therefore it is unnecessary to double count such manholes and conduit when used occasionally for the routing of a distribution backbone cable.

In a "campus environment," where underground structure is used, it is owned and operated by the owner of the campus and not the ILEC. The cable is treated as Intrabuilding Network Cable between buildings on one customer's premises, and the cost of such cable is not included in the model.

2.6. FILL AND INSTALLATION

2.6.1. Distribution Cable Fill Factors

Definition: The Hatfield Model uses the distribution cable fill factor input to calculate the size of cable needed to serve a given quantity of demand. HM 3.1 divides the number of pairs required in a distribution cable by this factor to determine the minimum number of pairs required, then uses the next larger available size cable.

Default Values:

Distribution Cable Fill Factors	
Density Zone	**Fill Factors**
0-5	.50
5-100	.55
100-200	.55
200-650	.60
650-850	.65
850-2,550	.70
2,550-5,000	.75
5,000-10,000	.75
10,000+	.75

Support: In determining appropriate cable size, an outside plant engineer is more interested in a sufficient number of administrative spares than in the percent fill ratio. The appropriate "target" distribution cable fill factor, therefore, will vary depending upon the size of cable. For example, 75% fill in a 2400 pair cable provides 600 spares. However, 50% spare in a 6 pair cable provides only 3 spares. Since smaller cables are used in lower density zones, Distribution Cable Fill Factors in HM 3.1 are lower in the lowest density zones to account for this effect.

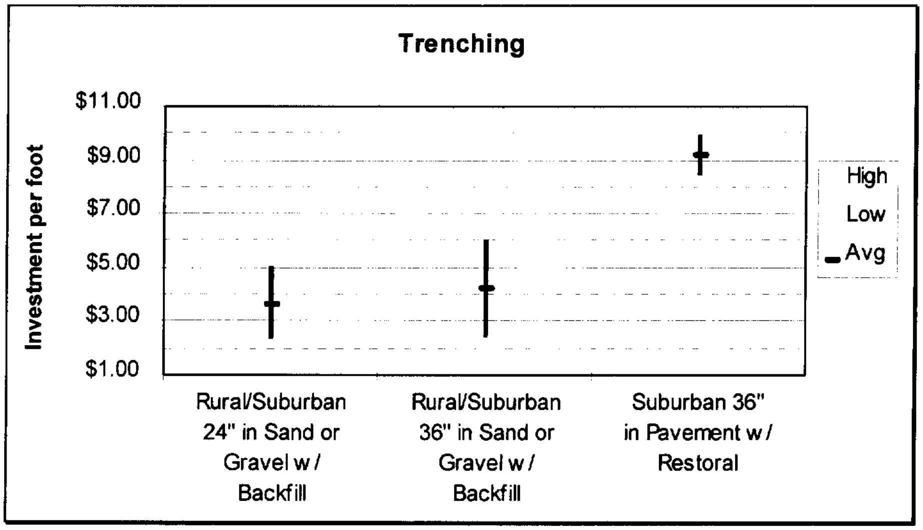
In general, the level of spare capacity provided by default values in the Hatfield Model (ver. 3.1) is sufficient to meet current demand plus some amount of growth. Because the model calculates the unit loop investment cost as the total loop investment (including spare capacity), divided by the current loop demand, the resulting unit costs are a conservatively high estimate of the economic cost of meeting current loop demand. This occurs because some of the spare distribution plant can and will be used to satisfy additional loop demand in the future, without causing any additional investment cost. Thus, the Hatfield Model (ver. 3.1) default values for the distribution cable fill factors are conservatively low from an economic costing standpoint.

2.6.2. Distribution Conduit Placement Cost/Foot

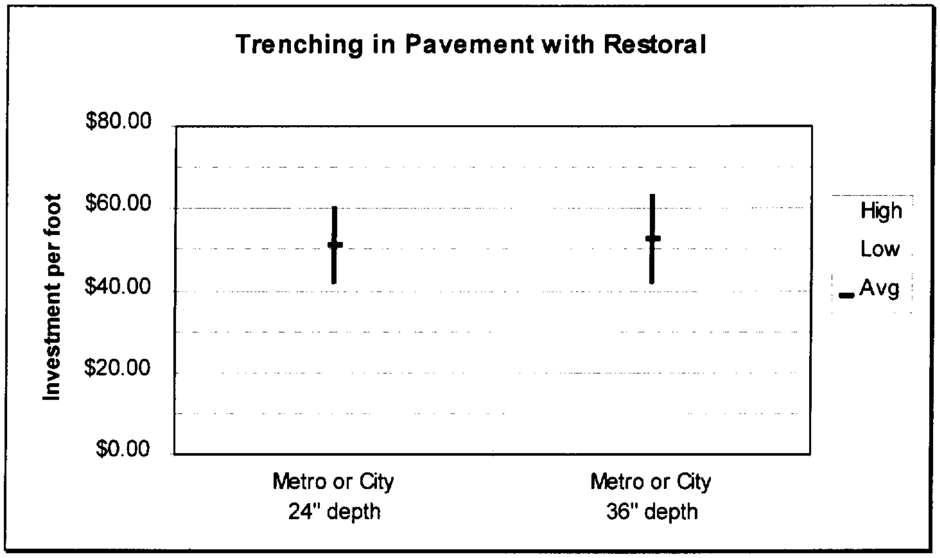
Definition: The cost per foot to provide a trench, place 4" PVC conduit pipes, backfill the trench with appropriate screened fill, and restoration of surface conditions. The material cost of the PVC conduit pipe is covered under "Conduit Material Investment per foot", and is affected by the number of copper distribution cables placed in a conduit run, and the number of "Spare tubes per Route (distribution)."

Accounting treatment for limited use of conduit in protecting buried cable, where a manhole is not involved, is classified to the buried account. "The cost of pipes or other protective covering for underground drop and block wires shall be included in Account 2421, Aerial Cable or Account 2423, Buried Cable, as appropriate.[14]

Default Values:



[14] Ibid., Para 32.2441 (d) Conduit systems.



Distribution Structure Conduit Placement/Installation Cost/Foot						
Density	Designation	Trench in Dirt & Place PVC $/ft.	% Used	Trench in Pavement & Place PVC $/ft.	% Used	Composite Average
0-5	Rural	$3.40	35%	$14.00	65%	$10.29
5-100	"	$3.40	35%	$14.00	65%	$10.29
100-200	"	$3.40	35%	$14.00	65%	$10.29
200-650	"	$3.40	25%	$14.00	75%	$11.35
650-850	Rural/Subn	$3.40	20%	$14.00	80%	$11.88
850-2,550	Suburban	$4.50	15%	$18.50	85%	$16.40
2,550-5,000	Subn/Urbn	$4.50	10%	$23.50	90%	$21.60
5,000-10,000	Urban	$6.00	10%	$55.00	90%	$50.10
10,000+		N/A	N/A	$75.00	100%	$75.00

Distribution Structure Conduit Placement/Installation Cost/Foot	
Density Zone	Cost/ft.
0-5	$10.29
5-100	$10.29
100-200	$10.29
200-650	$11.35
650-850	$11.88
850-2,550	$16.40
2,550-5,000	$21.60
5,000-10,000	$50.10
10,000+	$75.00

Support: Costs for various trenching methods were estimated by a team of experienced outside plant experts. Additional information was obtained from printed sources.

Use of underground conduit structure should be infrequent, especially in the lower density zones. Conduit placement cost is essentially the same, whether it be to house distribution cable, feeder cable, interoffice cable, or other telecommunication carrier cable, including CATV. Although use of conduit for distribution cable in lower density zones is not expected, default prices are shown above, should a user elect to change parameters for percent underground, aerial, and buried structure allowed by the HM 3.1 model structure. The default values shown above are the same for underground feeder and underground distribution.

2.6.3. Distribution Buried Installation Cost/Foot

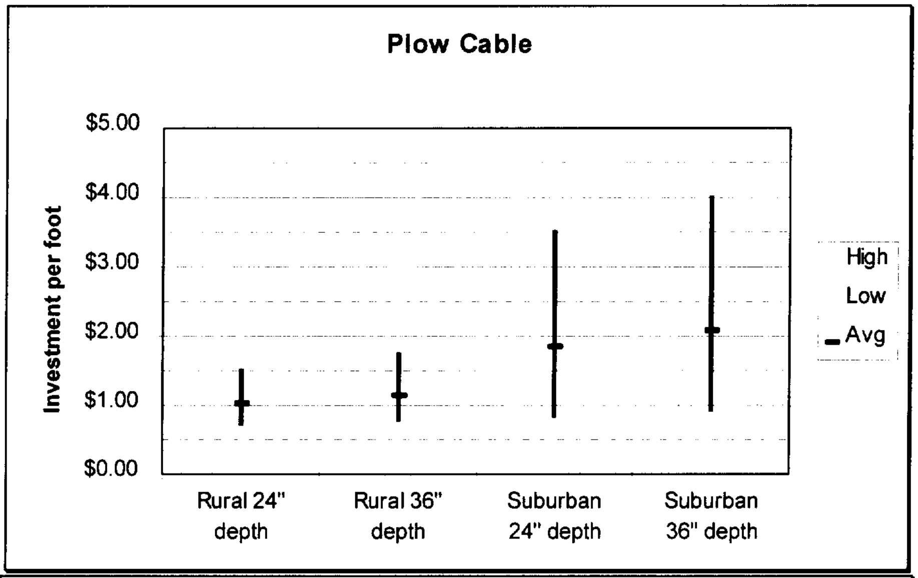
Definition: The cost per foot of placing distribution cable in trenches.

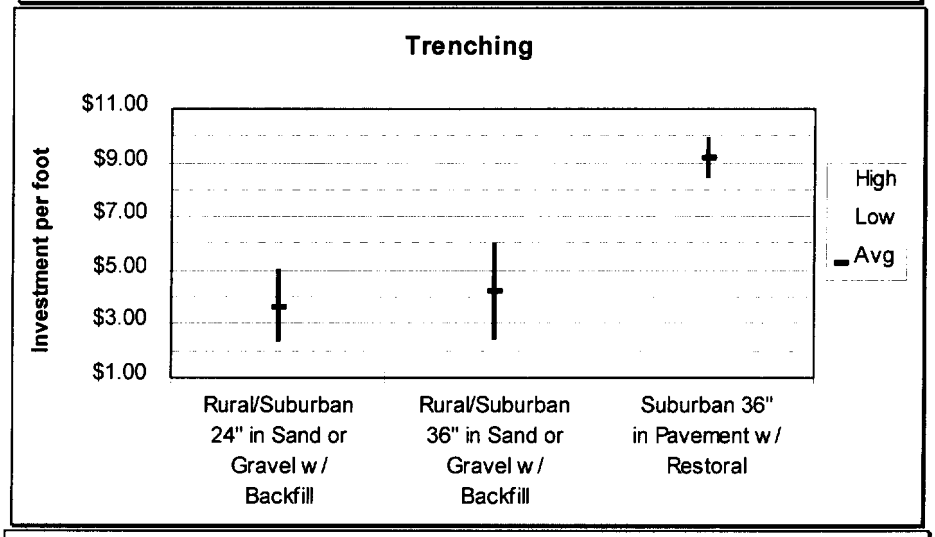
Default Values:

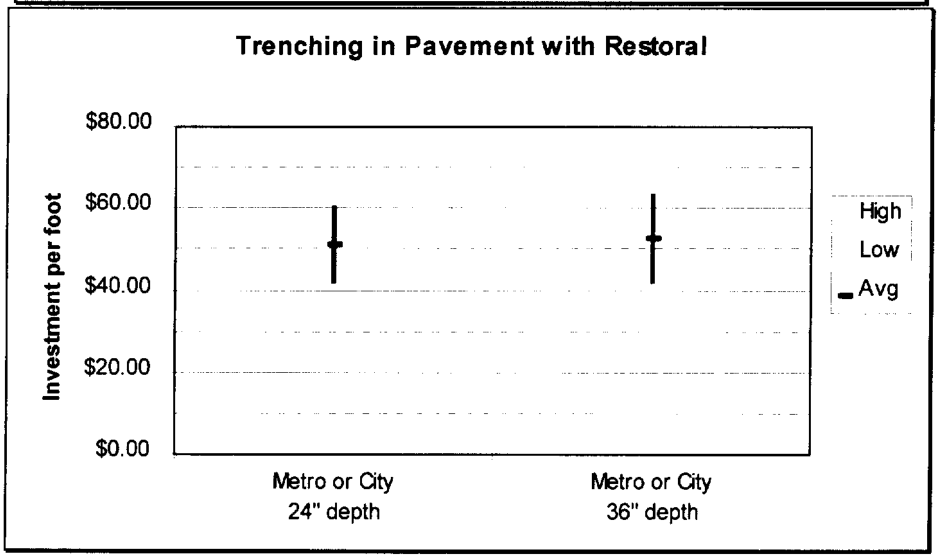
Distribution Buried Installation Cost/Foot	
Density Zone	Cost/ft.
0-5	$1.77
5-100	$1.77
100-200	$1.77
200-650	$1.93
650-850	$2.17
850-2,550	$3.54
2,550-5,000	$4.27
5,000-10,000	$13.00
10,000+	$45.00

Support: Costs for various trenching methods were estimated by a team of experienced outside plant experts. Additional information was obtained from printed resources[15]. Still other information was provided by several contractors who routinely perform excavation, conduit, and manhole placement work for telephone companies. Results of those inquiries are revealed in the following charts. Note that this survey demonstrates that costs do not vary significantly between buried placements at 24" underground versus 36" underground.

[15] Martin D. Kiley and Marques Allyn, eds., *1997 National Construction Estimator 45th Edition*, pp. 12-15.


Plow Cable
Investment per foot
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
Rural 24" depth
Rural 36" depth
Suburban 24" depth
Suburban 36" depth
High
Low
Avg


Trenching
Investment per foot
$11.00
$9.00
$7.00
$5.00
$3.00
$1.00
Rural/Suburban 24" in Sand or Gravel w / Backfill
Rural/Suburban 36" in Sand or Gravel w / Backfill
Suburban 36" in Pavement w / Restoral
High
Low
Avg


Trenching in Pavement with Restoral
Investment per foot
$80.00
$60.00
$40.00
$20.00
$0.00
Metro or City 24" depth
Metro or City 36" depth
High
Low
Avg

Distribution Structure Buried Placement/Installation Cost/Foot								
Density	Designation	Plow $/ft.	% Used	Trench in Dirt $/ft.	% Used	Trench in Pavement	% Used	Composite Average
0-5	Rural	$0.80	60%	$2.40	35%	$9.00	5%	$1.77
5-100	"	$.80	60%	$2.40	35%	$9.00	5%	$1.77
100-200	"	$.80	60%	$2.40	35%	$9.00	5%	$1.77
200-650	"	$.80	50%	$2.40	45%	$9.00	5%	$1.93
650-850	Rural/Subn	$.80	35%	$2.40	60%	$9.00	5%	$2.17
850-2,550	Suburban	$1.20	20%	$3.50	75%	$13.50	5%	$3.54
2,550-5,000	Subn/Urbn	$1.20	10%	$3.50	80%	$13.50	10%	$4.27
5,000-10,000	Urban	N/A	N/A	$5.00	80%	$45.00	20%	$13.00
10,000+	Urban	N/A	N/A	N/A	N/A	$45.00	100%	$45.00

2.6.4. Distribution Pole Spacing

Definition: Spacing between poles supporting aerial distribution cable.

Default Values:

Distribution Pole Spacing	
Density Zone	Spacing
0-5	250
5-100	250
100-200	200
200-650	200
650-850	175
850-2,550	175
2,550-5,000	150
5,000-10,000	150
10,000+	150

Support: Distances between poles are larger in more rural areas for a several reasons. Poles are usually placed on property boundaries, and at each side of road intersections (unless cable is run below the road surface in conduit). Property boundaries tend to be farther apart in less dense areas, and road intersections are also farther apart.

Depending on the weight of the cable, and the generally accepted guideline that sag should not exceed 10 feet at mid-span, while still maintaining appropriate clearances as designated by the National Electric Safety Code, very long spans between poles may be achieved. This length may be as great as 1,500 feet using heavy gauge strand and very light cable, or may be shorter for heavier cables.[16] In practice, much shorter span distances are employed, usually 400 feet or less.

"...where conditions permit, open wire spans can approach 400 feet in length with practical assurance that the lines will withstand any combination of weather condition. Longer spans mean savings in construction costs and a net reduction in over-all plant investment, including fewer poles to buy, smaller quantity of

[16] Bellcore, *Clearance for Aerial Cable and Guys in Light, Medium and Heavy Loading Areas, (BR 627-070-015), Issue 1*, 1987.
see also, Bellcore, *Clearances for Aerial Plant, (BR 918-117-090), Issue 5*, 1987.
see also, Bellcore, *Long Span Construction (BR 627-370-XXX)*, date unk.

pole hardware required, and less construction time. The use of long spans also means a reduction in maintenance expense."[17]

2.7. GEOLOGY AND CLUSTERS

2.7.1. Distribution Multiplier, Difficult Terrain

Definition: The amount of extra distance required to route distribution and feeder cable around difficult soil conditions, expressed as a multiplier of the distance calculated for normal situations.

Default Value: 1.2

Support: HM 3.1 treats difficult buried cable placement in rock conditions using four parameters: 1) Distribution Multiplier, Difficult Terrain; 2) Rock Depth Threshold, inches; 3) Hard Rock Placement Multiplier; and 4) Soft Rock Placement Multiplier. Where USGS data indicates the presence of rock closer to the surface for a portion of the CBG, the Hatfield Model imposes additional costs. None of the multipliers apply until until subsurface rock conditions are close enough to the surface to affect the placement of buried cable (Rock Depth Threshold: Default = 24 inches).

The typical response to hard rock conditions is to simply route cable around those conditions where rock is within the threshold depth (24 inches). HM 3.1 conservatively assigns an additional 20 percent to the cable length every time it encounters bedrock at less than 2 feet. Assigning this extra 20% represents application of good engineering judgment.

2.7.2. Rock Depth Threshold, inches

Definition: The depth of bedrock, above which (that is, closer to the surface) additional costs are incurred for placing distribution or feeder cable.

Default Value: 24 inches

Support: Cable is normally placed at a minimum depth of 24 inches. Shallower cover may also occur. certainly no less than 12 inches is known to occur in unusual cases. Where USGS data indicates the presence of rock closer to the surface, HM 3.1 imposes additional costs.

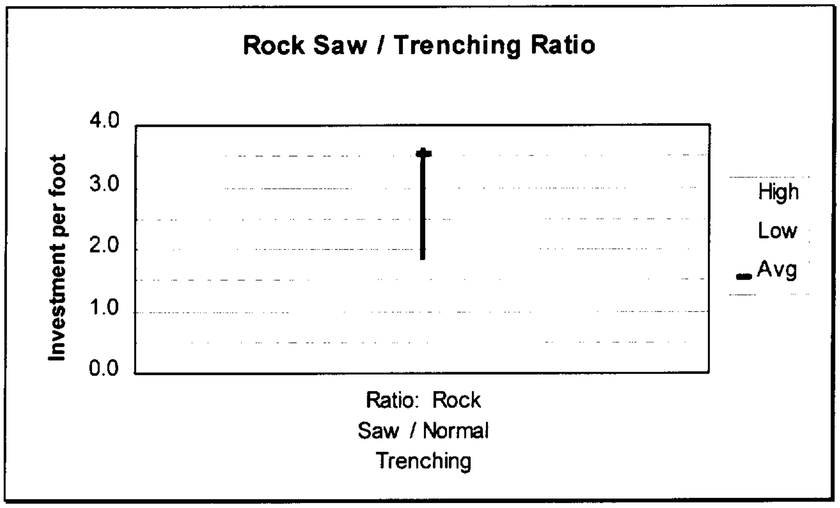
2.7.3. Hard Rock Placement Multiplier

Definition: The increased cost required to place distribution or feeder cable in bedrock classified as hard, when it is within the rock depth threshold of the surface, expressed as a multiplier of normal installation cost per foot.

Default Value: 3.5

Support: A rock saw is used whenever hard rock must be excavated. Information received from independent contractors who perform this type of work is reflected below. Hard rock costs are reflected at the top of the scale.

[17] Lee, Frank E., *Outside Plant, abc of the Telephone Series, Volume 4*, abc TeleTraining, Inc., Geneva, IL, 1987, p. 41.



2.7.4. Soft Rock Placement Multiplier

Definition: The increased cost required to place distribution or feeder cable in bedrock classified as soft, when it is within the rock depth threshold of the surface, expressed as a multiplier of normal installation cost per foot.

Default Value: 2.0

Support: A rock saw or tractor-mounted ripper is used whenever soft rock must be excavated. Information received from independent contractors who perform this type of work is reflected below. Soft rock costs are reflected at the lower end of the scale in the figure in section 2.7.3.

2.7.5. Distribution Multiplier, Difficult Surface

Definition: The increased cost required to place distribution or feeder cable due to difficult soil conditions, expressed as a multiplier of the normal installation cost per foot.

Default Value: 1.0

Support: HM 3.1 can adjust buried placement costs if soil conditions so require. Information received from independent contractors who perform this type of work indicate that the variability of bids, and availability of adequate workforce affects costs more than particular soil types. HM 3.1 therefore uses a default value of 1.0

2.7.6. Sidewalk / Street Fraction

Definition: The fraction of small (< .03 sq. mile) downtown CBGs that are streets and sidewalks.

Default Value: .20

2.7.7. Local RT (per cluster) thresholds – Maximum Total Distance

Definition: The maximum potential distribution length, in feet, above which Remote Terminals are located at the center of each cluster, rather than at the center of the CBG, in order to reduce the remaining distribution length.

Default Value: 18,000

Support: The default value was chosen to be consistent with the minimum distance at which loading is usually required.[18]

2.7.8. Town Factor

Definition: The fraction of business and residential customers that are assumed to be located in towns, as opposed to surrounding areas, for those cases in which the model determines that population should be clustered in towns.

Default Value: .85

Support: Derived from data in the *Rand McNally Commercial Atlas and Marketing Guide-1995* and the *Statistical Abstract of the United States, 1995.*

2.7.9. Maximum Lot Size, in acres

Definition: The maximum effective lot size in a CBG, above which it is assumed that the population is clustered into areas whose effective lot size is the default value (that is, there is a cap on the amount of land – including common areas such as streets and parks -- each subscriber occupies).

Default Value: 3.0 acres

Support: Based on observations that subdivisions, towns, or other areas where a grid distribution structure is used rarely consist of plots greater than 3 acres.

2.7.10. Town Lot Size, in acres

Definition: The assumed lot size– including common areas such as streets and parks -- of subscribers residing in clusters within rural areas.

Default Value: 3.0 acres

Support: For clustering in rural areas the model calculates total cluster area as the sum of individual lot sizes. Larger lot sizes thus produce more distribution cable in this case. Assuming three acre lot sizes within a cluster yields a conservatively high cost estimate.

2.8. LONG LOOP ADJUSTMENTS

2.8.1. Loading Investment per Line

Definition: The investment required to add loading coils for copper distances greater than 18,000 feet, stated as the additional investment at various fixed break points.

Default Value:

[18] *BOC Notes on the LEC Networks - 1994*, Bellcore, p. 12-4.

Loading Investment per Line	
Distance	Investment
18,000	$20
27,000	$40
55,000	$75
99,000	$110
178,000	$175

2.8.2. Cable Gauge Multiplier

Definition: Multiplier of the material portion of the per foot cable investment to reflect the need for coarser gauge cable for copper distances greater than 18,000 feet, stated as the additional investment at various fixed break points.

Default Value:

Cable Gauge Multiplier	
Distance	Multiplier
18,000	1.36
27,000	2.55
55,000	2.55
99,000	13.07
178,000	13.07

2.8.3. DLC Channel Unit Adjustment

Definition: The increase in investment required for a DLC channel unit that can drive increased current through loops for copper distances greater than 18,000 feet, stated as the additional investment at various fixed break points.

Default Value:

DLC Channel Unit Adjustment	
Distance	Adjustment
18,000	1
27,000	1
55,000	1.25
99,000	1
178,000	1.25

Support: Coarser gauge wire is the most cost effective way to achieve dc resistance design limits from 0 to 55,000 ft. Beyond 55,000 ft., the Hatfield Model (ver. 3.1) uses a high current channel card at a 25% cost premium. Beyond 99,000 ft., 14 gauge copper is used, and a high current channel card is not required. Beyond 178,000 ft., both 14 gauge copper and a high current channel card are required to meet resistance design standards.

2.9. SAI INVESTMENT

Definition: The installed investment in the SAI that acts as the physical interface point between distribution and feeder cable.

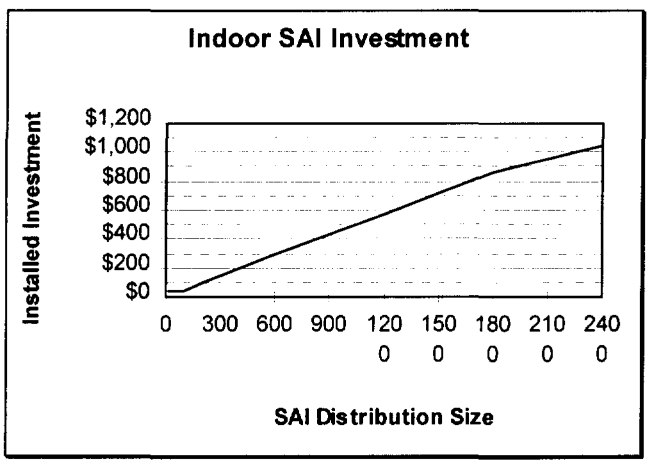
Default Values:

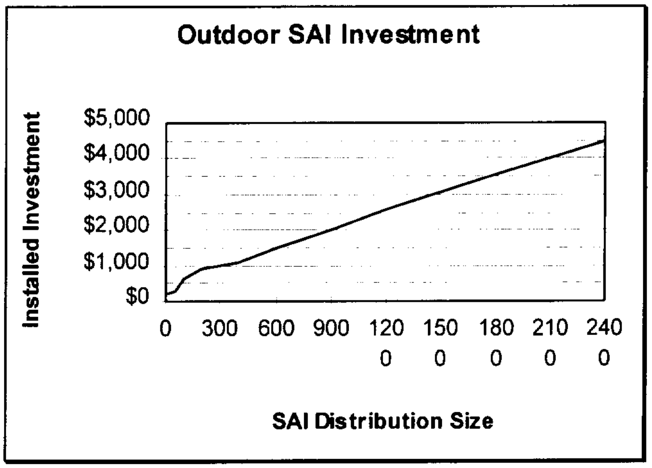
SAI Investment		
Cable Size	Indoor SAI	Outdoor SAI
2400	$1,052	$4,469
1800	$864	$3,569
1200	$576	$2,610
900	$432	$2,028
600	$288	$1,500
400	$192	$1,071
200	$96	$902
100	$48	$642
50	$48	$300
25	$48	$250
12	$48	$250
6	$48	$250

Support: Indoor Serving Area Interfaces are used in buildings, and consist of simple terminations, or punch down blocks, and lightning protection where required. Equipment is normally mounted on a plywood backboard in common space.

Outdoor Serving Area Interfaces are more expensive, requiring steel cabinets that protect the cross connection terminations from the direct effects of water.

Prices are the opinion of a group of Engineering Experts.





3. FEEDER INPUT PARAMETERS

3.1. COPPER PLACEMENT

3.1.1. Copper Feeder Structure Fractions

Definition: The relative amounts of different structure types supporting sheath feet of copper feeder cable in each density zone. Aerial feeder cable is attached to telephone poles, buried cable is laid directly in the earth, and underground cable runs through underground conduit.

Default Values:

Copper Feeder Structure Fractions			
Density Zone	Aerial/Block Cable	Buried Cable	Underground Cable (calculated)
0-5	.50	.45	*.05*
5-100	.50	.45	*.05*
100-200	.50	.45	*.05*
200-650	.40	.40	*.20*
650-850	.30	.30	*.40*
850-2,550	.20	.20	*.60*
2,550-5,000	.15	.10	*.75*
5,000-10,000	.10	.05	*.85*
10,000+	.05	.05	*.90*

Support: See discussion in section 2.5.1.

3.1.2. Copper Feeder Buried Installation Cost/Foot

Definition: The cost per foot of placing buried copper feeder cable.

Default Values:

Copper Feeder Buried Installation Cost/Foot	
Density Zone	Cost/ft.
0-5	$1.77
5-100	$1.77
100-200	$1.77
200-650	$1.93
650-850	$2.17
850-2,550	$3.54
2,550-5,000	$4.27
5,000-10,000	$13.00
10,000+	$45.00

Support: See discussion in section 2.6.3.

3.1.3. Copper Feeder Conduit Installation Cost/Foot

Definition: The cost per foot of placing underground conduit for copper feeder cable.

Default Values:

Copper Feeder Conduit Installation Cost/Foot	
Density Zone	Cost/ft.
0-5	$10.29
5-100	$10.29
100-200	$10.29
200-650	$11.35
650-850	$11.38
850-2,550	$16.40
2,550-5,000	$21.60
5,000-10,000	$50.10
10,000+	$75.00

Support: See discussion in section 2.6.2.

3.1.4. Copper Feeder Manhole Spacing, feet

Definition: The distance, in feet, between manholes for copper feeder cable.

Default Values:

Copper Feeder Manhole Spacing, feet	
Density Zone	Distance between manholes, ft.
0-5	800
5-100	800
100-200	800
200-650	800
650-850	600
850-2,550	600
2,550-5,000	600
5,000-10,000	400
10,000+	400

3.1.5. Copper Feeder Pole Spacing, feet

Definition: Spacing between poles supporting aerial copper feeder cable.

Default Values:

Copper Feeder Pole Spacing	
Density Zone	Spacing, ft.
0-5	250
5-100	250
100-200	200
200-650	200
650-850	175
850-2,550	175
2,550-5,000	150
5,000-10,000	150
10,000+	150

Support: See discussion in section 2.6.4.

3.1.6. Copper Feeder Pole Investment

Definition: The installed cost of a 40' Class 4 treated southern pine pole.

Default Value:

Pole Investment	
Materials	$201
Labor	$216
Total	*$417*

Support: See discussion in section 2.4.1.

3.1.7. Inner Duct Material Investment per foot

Definition: Material cost per foot of inner duct.

Default Value: $0.30

Support: Inner duct might permit more than one fiber cable per 4" PVC conduit. The model adds investment whenever fiber overflow cables are required.

3.2. FIBER PLACEMENT

3.2.1. Fiber Feeder Structure Fractions

Definition: The relative amounts of different structure types supporting fiber feeder cable in each density zone. Aerial feeder cable is attached to telephone poles, buried cable is laid directly in the earth, and underground cable runs through underground conduit.

Default Values:

Fiber Feeder Structure Fractions			
Density Zone	Aerial/Block Cable	Buried Cable	Underground Cable (calculated)
0-5	.35	.60	*.05*
5-100	.35	.60	*.05*
100-200	.35	.60	*.05*
200-650	.30	.60	*.10*
650-850	.30	.30	*.40*
850-2,550	.20	.20	*.60*
2,550-5,000	.15	.10	*.75*
5,000-10,000	.10	.05	*.85*
10,000+	.05	.05	*.90*

Support: See discussion in section 2.5.1.

3.2.2. Fiber Feeder Buried Installation, cost per foot

Definition: The cost per foot of placing buried fiber feeder cable in trenches.

Default Values:

Fiber Feeder Buried Installation, per foot	
Density Zone	Cost/ft.
0-5	$1.77
5-100	$1.77
100-200	$1.77
200-650	$1.93
650-850	$2.17
850-2,550	$3.54
2,550-5,000	$4.27
5,000-10,000	$13.00
10,000+	$45.00

Support: See discussion in section 2.6.3.

3.2.3. Fiber Feeder Conduit Installation, per foot

Definition: The cost per foot of placing underground conduit for fiber feeder cable.

Default Values:

Fiber Feeder Conduit Installation, per foot	
Density Zone	Cost/ft.
0-5	$10.29
5-100	$10.29
100-200	$10.29
200-650	$11.35
650-850	$11.38
850-2,550	$16.40
2,550-5,000	$21.60
5,000-10,000	$50.10
10,000+	$75.00

Support: See discussion in section 2.6.2.

3.2.4. Fiber Feeder Pullbox Spacing, feet

Definition: The distance, in feet, between pullboxes for underground fiber feeder cable.

Default Values:

Fiber Feeder Pullbox Spacing, feet	
Density Zone	Distance between pullboxes, ft.
0-5	2,000
5-100	2,000
100-200	2,000
200-650	2,000
650-850	2,000
850-2,550	2,000
2,550-5,000	2,000
5,000-10,000	2,000
10,000+	2,000

Support: Unlike copper manhole spacing, the spacing for fiber pullboxes is based on the practice of coiling spare fiber (slack) within pullboxes to facilitate repair in the event the cable is cut or impacted. Fiber feeder pullbox spacing is not a function of the cable reel lengths but rather a function of length of cable placed. The standard practice during the cable placement process is to provide for 5 percent excess cable to facilitate subsurface relocation, lessen potential damage from impact on cable, or provide for ease of cable splicing when cable is cut or damaged.[19] It is common practice for outside plant engineers to call for approximately 2 slack boxes per mile.

3.2.5. Buried Fiber Sheath Addition, per foot

Definition: The cost of dual sheathing for additional mechanical protection of buried fiber feeder cable.

Default Value: $0.20/foot

Support: Incremental cost for mechanical sheath protection on fiber optic cable is a constant per foot, rather than the ratio factor used for copper cable, because fiber sheath is approximately ½ inch in diameter, regardless of the number of fiber strands contained in the sheath. The incremental per foot cost was estimated by a team of experienced outside plant experts who have purchased millions of feet of fiber optic cable.

3.3. FILL FACTORS

3.3.1. Copper Feeder Cable Fill Factors

Definition: The spare capacity in a feeder cable, calculated as the ratio of the number of assigned pairs to the total number of available pairs in the cable.

Default Values:

[19] *Cable Construction Manual, 4th Edition*, CommScope, p. 75.

Copper Feeder Cable Fill Factors	
Density Zone	Fill Factors
0-5	.65
5-100	.75
100-200	.80
200-650	.80
650-850	.80
850-2,550	.80
2,550-5,000	.80
5,000-10,000	.80
10,000+	.80

Support: See discussion in section 2.6.1.

3.3.2. Fiber Feeder Fill Factor

Definition: Maximum fraction of fiber strands in a cable that are available to be used.

Default Values:

Fiber Feeder Fill Factor	
Density Zone	Fill Factor
0-5	1.00
5-100	1.00
100-200	1.00
200-650	1.00
650-850	1.00
850-2,550	1.00
2,550-5,000	1.00
5,000-10,000	1.00
10,000+	1.00

3.4. CABLE COSTS

3.4.1. Copper Feeder Cable, $/ foot

Definition: The investment per foot in copper feeder cable, engineering, installation, and delivery.

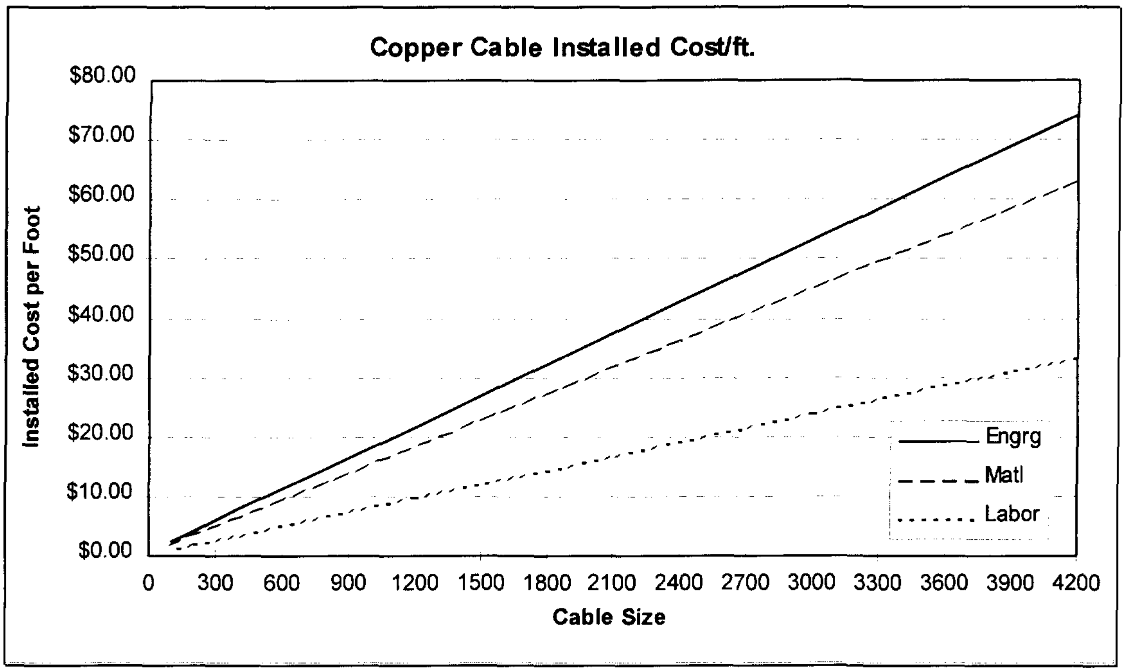
Default Values:

Copper Feeder Investment, per foot	
Cable Size	**$/foot (u/g & aerial)**
4200	$74.25
3600	$63.75
3000	$53.25
2400	$42.75
1800	$32.25
1200	$21.75
900	$16.50
600	$11.25
400	$7.75
200	$4.25
100	$2.50

Support: Outside plant planning engineers commonly assume that the cost of cable material can be represented as an a + bx straight line graph. In fact, Bellcore Planning tools, EFRAP I, EFRAP II, and LEIS:PLAN have the engineer develop such an a + bx equation to represent the cost of cable. As technology, manufacturing methods, and competition have advanced, the price of cable has been reduced. While in the past, the cost of copper cable was typically ($.50 + $.01 per pair) per foot, current costs are typically ($.30 + $.007 per pair) per foot.

In the opinion of expert outside plant engineers material represents approximately 40% of the total installed cost. This is a widely used rule of thumb among outside plant engineers. Experience of outside plant experts used for developing the HM 3.1 includes writing and administering hundreds of outside plant "estimate cases" (undertakings over $35,000). Outside plant engineering experts have agreed that 40% material to total installed cost is a good approximation. Such expert opinions were also used to determine that the average engineering content for installed copper cable is 15% of the installed cost. The remaining 45% represent direct labor for placing and splicing cable.

The following chart represents the default values used in the model.



3.4.2. Fiber Feeder Cable, $/foot

Definition: The investment per foot in fiber feeder cable, engineering, installation, and delivery.

Default Values:

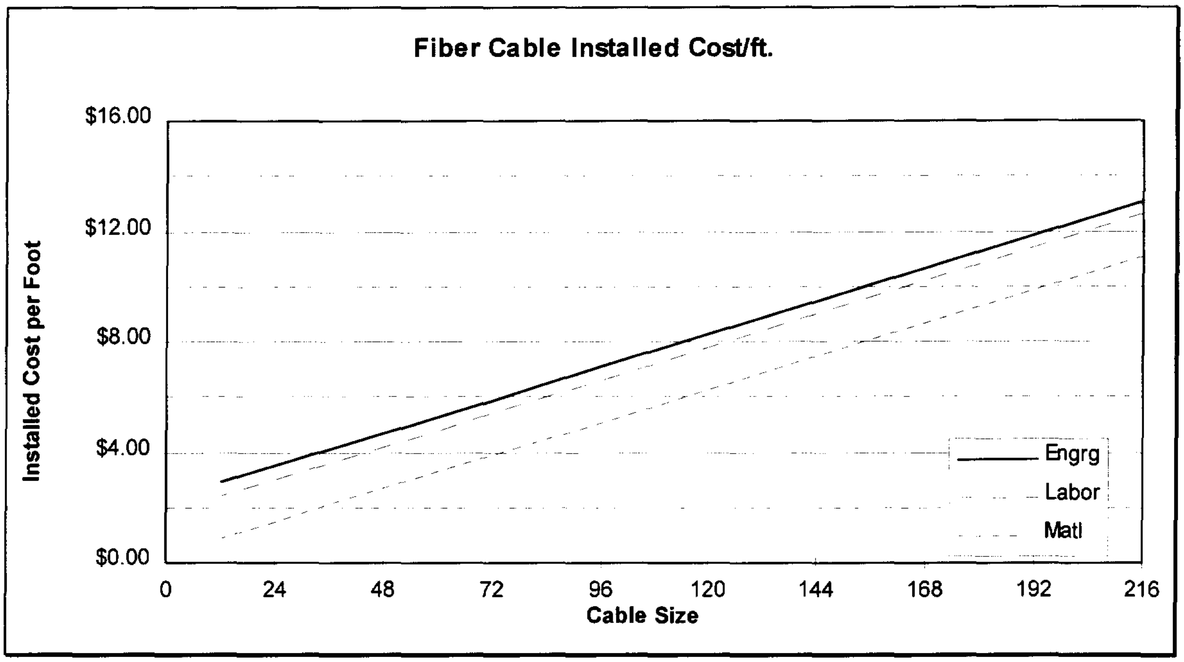
Fiber Feeder Investment, per foot	
Cable Size	$/foot (u/g & aerial)
216	$13.10
144	$9.50
96	$7.10
72	$5.90
60	$5.30
48	$4.70
36	$4.10
24	$3.50
18	$3.20
12	$2.90

Support: Outside plant planning engineers commonly assume that the cost of cable material can be represented as an a + bx straight line graph. In fact, Bellcore Planning tools, EFRAP I, EFRAP II, and LEIS:PLAN have the engineer develop such an a + bx equation to represent the cost of cable. As technology, manufacturing methods, and competition have advanced, the price of cable has been reduced. While in the past, the cost of copper cable was typically ($.50 + $.10 per fiber) per foot, current costs are typically ($.30 + $.05 per fiber) per foot.

Splicing Engineering and Direct Labor are included in the cost of the Remote Terminal Installations, and the Central Office Installations, since field splicing is unnecessary with fiber cable pulls as long as 35,000 feet between splices.

Placing Engineering and Direct Labor are estimated at $2.00 per foot, consisting of $0.50 in engineering per foot, plus $1.50 direct labor per foot. These estimates were provided by a team of Outside Plant Engineering and Construction experts.

The following chart represents the default values used in the model.



3.5. DLC EQUIPMENT

3.5.1. DLC site and power per remote terminal

Definition: The investment in site preparation and power for the remote terminal of a Digital Loop Carrier (DLC) system.

Default Values:

Remote Terminal Site and Power	
TR-303 DLC	Low Density DLC
$3,000	$2,500

Support: The incremental per site cost was estimated by a team of experienced outside plant experts who have contracted for hundreds of Remote Terminal site installations. Low Density DLC requires less space.

3.5.2. Maximum Line Size per Remote Terminal

Definition: The maximum number of lines supported by the initial line module of a remote terminal.

Default Values:

Maximum Line Increment per Remote Terminal	
TR-303 DLC	Low density DLC
672	96

Support: The standard increment for large fiber optic multiplexers is an OC-3 multiplexer equipped to operate at the OC-1 rate of approximately 50 Mbps. This basic unit provides 28 DS-1s, which can carry 24 DS-0 POTS circuits each. This equates to 672 POTS lines. Although TR-303 allows other concentrations, this is the most common standard used by multiple vendors of Integrated Digital Loop Carrier Systems.

A variety of low density digital loop carrier systems exist in the market today. The Hatfield Model (ver. 3.1) utilizes an integrated configuration, whereby a 96 line unit can home on a standard 672 base terminal. Several of these can be used before moving to the larger 672 line system.

3.5.3. Remote terminal fill factor

Definition: The line unit fill factor in a DLC remote terminal, that is, the ratio of lines served by a DLC remote terminal to the number of line units equipped in the remote terminal.

Default Values:

Remote Terminal Fill Factors	
TR-303 DLC	Low Density DLC
.90	.90

Support: The most expensive part of integrated digital loop carrier provisioning is the digital to analog conversion that takes place in the Remote Terminal line card. This expensive card (HM3.1 defaults to $310 per 4 line card) calls for stringent inventory control on the part of the ILEC. Also, fill factors are largely a function of the time frame needed to provide incremental additions. Since line cards are a highly portable asset, facility relief can be provided by dispatching a technician with line cards, rather than engaging in a several month long copper cable feeder addition. Therefore high fill rates should be the norm for an efficient provider using forward looking technology.

3.5.4. DLC initial common equipment investment

Definition: The cost of all common equipment and housing in the remote terminal, as well as the fiber optics multiplexer required at the CO end for the initial line module of the DLC system (assumes integrated digital loop carrier (IDLC)).

Default Values:

Remote Terminal Initial Common Equipment Investment	
TR-303 DLC	Low Density DLC
$66,000	$13,000

Support: The cost of an initial increment of Integrated Digital Loop Electronics was estimated by a team of experienced outside plant experts who have contracted for hundreds of Remote Terminal site installations. Low Density DLC requires less initial investment.

3.5.5. DLC channel unit investment

Definition: The investment in channel units required in the remote terminal of the DLC system.

Default Values:

TR-303 and low density DLC channel unit investment per unit	
POTS Channel Unit	Coin Channel Unit
$310	$250

Support: The cost of individual POTS Channel Unit Cards was estimated by a team of experienced outside plant experts who have purchased over a million of these cards from suppliers.

3.5.6. DLC Lines per CU

Definition: The number of lines that can be supported on a single DLC channel unit.

Default Values:

TR-303 and low density DLC Lines per channel unit	
POTS	Coin
4	2

Support: All major market leaders in this technology supply channel units that provide for 4 POTS lines per card, or 2 COIN lines per card. This is common knowledge among technical telecommunications professionals, and can be verified by calls to major manufacturers, or a review of their published materials.

3.5.7. Low Density DLC to TR-303 DLC Cutover

Definition: The threshold number of lines served, above which the TR-303 DLC will be used.

Default Value: 384

Support: An analysis of initial costs reveals that 4 Low Density DLC units, at 96 lines each, are more cost effective than a single large IDLC unit with a capacity of 672 lines. Beyond 4 Low Density DLC units, the larger unit is less costly.

3.5.8. Fibers per remote terminal

Definition: The number of fibers connected to each DLC remote terminal, including one for upstream transmission, one for downstream transmission, and two for redundancy.

Default Values:

Fibers per Remote Terminal	
TR-303 DLC	Low density DLC
4	4

Support: All standard fiber optic multiplexers manufactured for at least the past 15 years have used this configuration which includes a 100 percent hot standby backup for the transmit and receive paths. This configuration is common knowledge among technical telecommunications professionals.

3.5.9. Optical Patch Panel

Definition: The investment required for each optical patch panel associated with a DLC remote terminal.

Default Values: